UNDERSTANDING MATHEMATICS TEACHERS' COLLABORATIVE SENSEMAKING IN THE CONTEXT OF TEACHERS' LEARNING ECOLOGIES

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Over the last two decades, researchers have portrayed quality professional development for mathematics teachers as collaborative and situated in teachers' instructional realities. However, empirical findings also point out various impediments to transforming teacher conversations into consequential learning. These findings illuminate the need to acknowledge additional resources that teachers bring to professional interactions and the need for ever more nuanced theories of teacher learning to inform teacher educators' work. Inspired by ecological models of learning, in this conceptual paper I work towards understanding teachers' collaborative sensemaking as part of broader teacher learning ecologies. I distinguish and name possible scopes and contexts for the study of teacher learning in conversations about instruction, and then identify directions for future research towards stronger connections between immediate and broader contexts.

Keywords: Learning Theory, Professional Development

Over the last two decades, many researchers have explored and documented ways to support teachers towards teaching rich mathematical content with extended student engagement, and more recently, with additional layers of responsiveness to the multiple cognitive, social, cultural and political dimensions of student learning. The resulting studies portray quality professional development (PD) as collaborative and situated in teachers' instructional context (Ball & Cohen, 1999; Borko et al., 2008; Horn, 2005; Horn & Garner, 2022; Kazemi & Hubbard, 2008). Here, I refer to these designs as Collaborative Sensemaking as Professional Development (CSPD). The situated nature of CSPD breaks away from prescription-based pedagogies that teachers often experience in typical top-down PD workshops (Kazemi & Hubbard, 2008), and its collaborative nature potentially counters the isolation that teachers often experience in schools (Lortie, 1975; Little, 1990). Other significant affordances of CSPD include providing teachers with opportunities to develop their adaptive expertise (Horn & Garner, 2022; Lefstein & Snell, 2013); supporting teachers in reconciling different perspectives on teaching (Ehrenfeld et al., 2020; van Es, 2012); and working towards more productive norms of participation in conversations about instruction (Horn & Little, 2010).

However, empirical findings also point out material, social, cultural, emotional, and cognitive impediments to transforming teacher conversations into consequential learning (Borko et al., 2008; Horn et al., 2017; Vedder-Weiss et al., 2018). For example, Horn & Kane (2015) provided evidence that limited engagement with rich conceptual resources in teacher workgroups results in limited learning opportunities, and vice versa. These findings illuminate the need to acknowledge additional resources that teachers bring to professional interactions and provide teachers with structures to reconcile these resources with local contexts. More generally, tensions between the potential and impediments for learning in CSPD underscore the need for ever more nuanced theories of teacher learning to inform teacher educators' work (Clarke & Hollingsworth, 2002; Horn, 2005; Horn & Garner, 2022; Opfer & Pedder, 2011).

Although researchers of teacher learning in conversations typically adopt sociocultural, situated and situative perspectives (Greeno, 2006; Lave & Wenger, 1991; Vygotsky, 1980)—all

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of which underscore the importance of context in interaction and learning—it is not always clear what contexts warrant careful attention, and which are overlooked. That is a theoretical and analytical gap central to this conceptual paper. As a review of teacher professional conversations by Lefstein et al. (2020) suggests, studies of teacher collaboration most often consider the immediate interactional context of learning, sometimes consider the institutional context of school and seldom acknowledge broader contexts, such as the multiple experiences teachers have in different settings external to school, or broader macro-level social structures. While some studies account for some of these aspects of teacher learning, there is nothing in the framing of sociocultural, situated, and situative perspectives that guides researchers towards being explicit and mindful of the contexts they account for and which they ignore.

Inspired by researchers of learning and development that take ecological perspectives (Bronfenbrenner, 1979; Erickson, 2004; Nasir et al., 2020), my overall goal is to understand CSPD environments in ways that account for the broader contexts of teacher learning ecologies, with a focus on the interactive impacts of multiple experiences in different settings, and social structures within which teachers work. Consequently, I ask *How can ecological models of learning inform research on mathematics teacher learning in CSPD settings?*

First, I discuss ecological perspectives on learning, with a focus on Bronfenbrenner's (1979) framework for studying the ecology of human development. Then, to distinguish and name possible scopes and contexts within teacher learning ecologies, I build on Bronfenbrenner's work and adapt it to the specific case of teacher learning. Finally, I move beyond distinguishing and naming contexts towards studying them as interrelated. In the final section I discuss how additional ecological models of learning (Cobb et al., 2018; Engeström, 2001; Erickson, 2004; Gutiérrez & Jurow, 2016; Horn et al., 2013; Hutchins, 1995; Nasir et al., 2020) can inform future research towards stronger connections between the immediate and broader contexts of teacher learning ecologies.

An Ecological Perspective on Learning

For the last four years, I have been part of a PD effort to support instructional growth among secondary mathematics teacher teams (Project SIGMa; Horn & Garner, 2022). Using the conceptualization of PD I introduced earlier, SIGMa would be considered CSPD, since it builds on teacher community and dialogue to respond to teachers' perceived instructional puzzles. Within this project, we learned about the teachers' personal and professional histories, their relationships with colleagues and students, and their approaches towards math teaching. Through these relationships, it became clear that the teachers' ongoing learning in the intervention was strongly related to other activities they participated in, such as workshops with our research partners, a professional development organization, ongoing conversations with colleagues, and their experiences in previous schools. This insight might seem obvious, but it stands in sharp contrast to the ways math teachers' professional learning in PD is typically examined within single activities or programs, with little to no attention to external settings and broader contexts.

Bronfenbrenner's Ecology of Human Development

Bronfenbrenner's (1979) framework provides a generalizable (Shelton, 2019) starting point for studying how teachers and their environments interact in professional development processes. Studying development "in context" could mean many things. Bronfenbrenner's call was not to study development "in context" in some general sense of development "in the real world" or "not in the laboratory" but rather to think about development in the specific context that is an ecological system, as he defines it (Bronfenbrenner, 1979; see also about his work in

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Christensen, 2016; Shelton, 2019; Xia et al., 2020). It is hard to overstate the importance of this distinction for the study of teacher learning. As I mentioned, while researchers of teacher conversations often underscore the importance of context, they mainly consider the immediate local social situation and seldom acknowledge broader contexts. Considering broader contexts and their interactive impacts is essential for integrating issues such as power dynamics, class realities, and racial tensions more seriously into analysis of teacher conversation, and consequently, into teacher collaborative sensemaking.

Beyond the Microsystem

Bronfenbrenner's framework includes a collection of four nested structures of environment: microsystem, mesosystem, exosystem, and macrosystem. *Microsystems* represent the immediate settings in which the developing people engage in activities, relationships, and roles; all of which are directly influenced from participation in other settings. *The mesosystem*, rather than a layer that surrounds the microsystem, represents the relationships between two or more settings. For example, Bronfenbrenner discussed the case of mothers from two-parent families with part time jobs. Their partners might act as if they are full time mothers, and employers as if they are full time employees. The mothers themselves might experience the resulting frustration as parents, on the job, and more generally as human beings. (Bronfenbrenner, 1979, p. 212). In sum, participation in more than one setting has developmental consequences that are overlooked when we only attend to the immediate interactional context. *The exosystem* consists of settings in which the focal people of interest are not actively involved, but others who interact with them are. For example, for a child, if we consider the relations between home and school as a mesosystem, then the parents' workplace or social lives could be considered part of their exosystem, even if the child is not physically attending these settings. *The macrosystem* relates to the larger social and cultural structures within which development is taking place, including values, practices, resources, and the different types of identities they invite or discourage.

Interactive Impact of Multiple Contexts

According to reviews of literature by Tudge et al. (2009, 2016) many researchers wrongly see Bronfenbrenner's framework as a theory about the influence of context on development and use it to ask questions about the direct linear effects of individual factors (i.e., a "reductionist" or "mechanist" paradigm). In contrast, Bronfenbrenner's four nested structures of the environment are meant as a framework for exploring how different factors act synergistically towards multiplicative and non-linear outcomes. To adapt this perspective onto the realms of teacher learning, we would need to explore both the internal properties of CSPD settings themselves and how they gain their local meanings from their positioning in broader teacher learning ecologies.

Operationalizing Mathematics Teachers' Learning Ecologies

From a teacher perspective, teacher learning happens across time and settings, through a complex web of learning experiences. In contrast, a typical linear pathway perspective for teacher learning in PD assumes (often implicitly) that teachers attend PD where they develop their knowledge and beliefs, which, in turn, change their teaching practices and eventually improve students' learning (see Figure 1; Clarke & Hollingsworth, 2002). It too often focuses on the direct effects of PD interventions, where learning itself is an indicator of the effectiveness of specific curricula, programs, or core-features of PD activity (Goldsmith et al., 2014). This tendency within the field of math education reflects more general trends in research of teacher learning towards listing certain features of activity as optimal for teacher learning (e.g., Desimone, 2009). A binary perspective on features of PD as absent or present is problematic

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because it overlooks their specifications and interactions, which are highly consequential for teachers' learning (Opfer & Pedder, 2011). In response to such trends, many point out the lack of well developed theories that take into account more complex and nonlinear approaches towards professional development (Clarke & Hollingsworth, 2002; Horn, 2005; Opfer & Pedder, 2011).

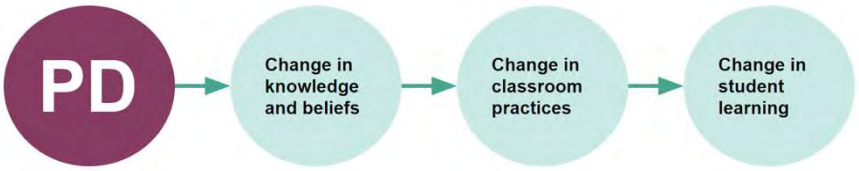

Figure 1: Linear Pathway Perspective (adapted from Clarke & Hollingsworth, 2002)

Inspired by Bronfenbrenner (1979) I suggest a framework for understanding teacher CSPD in the broader context of teacher learning ecologies. *The microsystems* included in this framework are the classroom, the settings of teacher collaborative sensemaking, informal teacher conversations, and other teacher learning settings such as PD workshops, conferences, organizations, and experiences in previous schools. *The school mesosystem* represents connections between classroom experiences, informal teacher conversations, and the focal collaborative and contextual PD setting. *The exosystem* represents connections to settings of teacher learning attended by one or more teachers or facilitators in the PD, but not necessarily by all (such as other PD workshops, conferences, organizations, and experiences in previous schools). *The macrosystem* represents the larger social and cultural structures within which the school operates, such as the school's neighborhood, or larger racial, ethnic, and civil structures. Figure 2 represents the suggested scope of an ecological perspective on teacher learning. Figure 3 represents possible contexts in the study of teacher learning in CSPD settings. Distinguishing and naming possible scopes and contexts for the study of teacher learning in CSPD settings can support researchers in being clearer about contexts they foreground and background in their design and analysis and for what reasons; in considering new aspects of learning that might be salient to their study; and in understanding the resources teachers bring to CSPD settings. The following vignette illustrates the framework as analytical lens for teacher conversations.

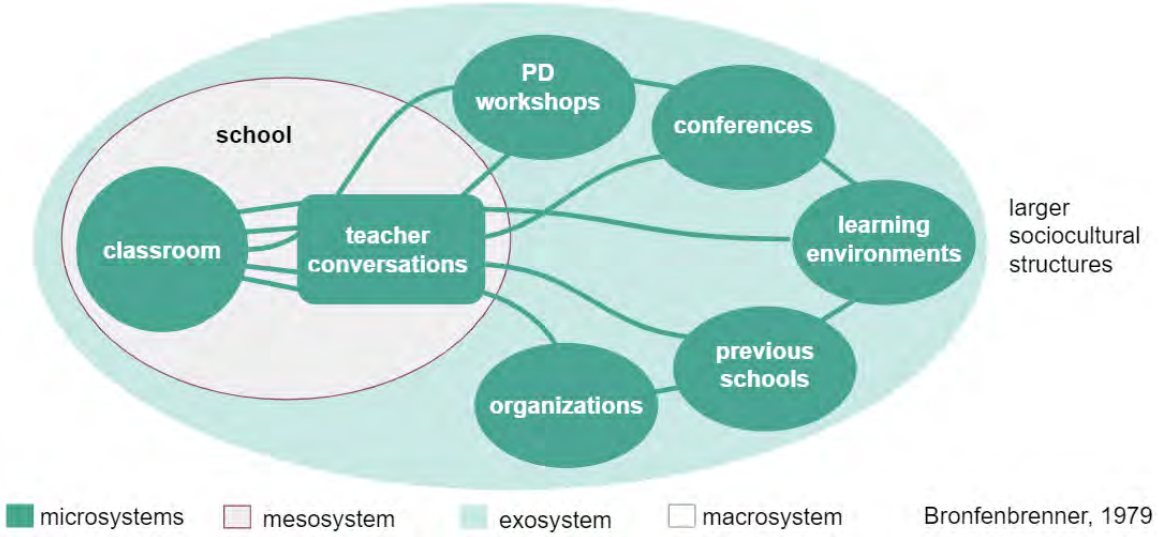

Figure 2: Suggested Scope of an Ecological Perspective on Teacher Learning in CSPD

Figure 3: Possible Contexts for the Study of Teacher Learning in CSPD

Vignette: Ezio and Veronica Discuss Grouping Strategies

To illustrate the analytical framework, consider the following vignette from Project SIGMa where two teachers discussed grouping strategies (for a careful analysis of this example see Ehrenfeld et al., 2020). In this conversation, the two teachers, Ezio and Veronica (pseudonyms), discussed Ezio's experiences in two different PD workshops: school-based Kagan training, where he learned about purposeful grouping (high and low achieving students in each group), and Park City Math Institute (PCMI), where he learned to group students randomly. Sharing his experience from the workshops, Ezio recalled how he first "did not agree" with PCMI random grouping. On the contrary, Kagan's purposeful grouping initially "made sense" to him. However, as the conversation progressed, Ezio and Veronica continued to make sense of these methods in light of their concern about tracking in their school. They discussed how purposeful grouping amplifies the consequences of tracking, in the shape of labeling kids as "dumb" or "awesome," while random grouping disrupts it. In addition, an interview with Ezio and Veronica revealed that they see tracking in their school as related to gentrification processes in their school's neighborhood. Their sense was that the principle was under pressure from newer and more affluent parents to increase tracking.

An ecological view of Ezio and Veronica's conversation highlights the following: First, teachers' opportunities to make sense of grouping strategies in the CSPD (microsystem), as an iterative process that involves experiments in the classroom (mesosystem) and experiences in two external PD workshops (exosystem). Second, it shows teacher agency with regards to both institutional structures of tracking (mesosystem) and broader social structures of gentrification (macrosystem) as structures to disrupt rather than to amplify. Third, it reveals other dimensions of the learning process, such as a trusting collegial relationship that affords ongoing inquiry into practice (microsystem). In sum, an ecological view of this example reveals learning in CSPD in

the context of their broader learning ecologies (see Figure 4).

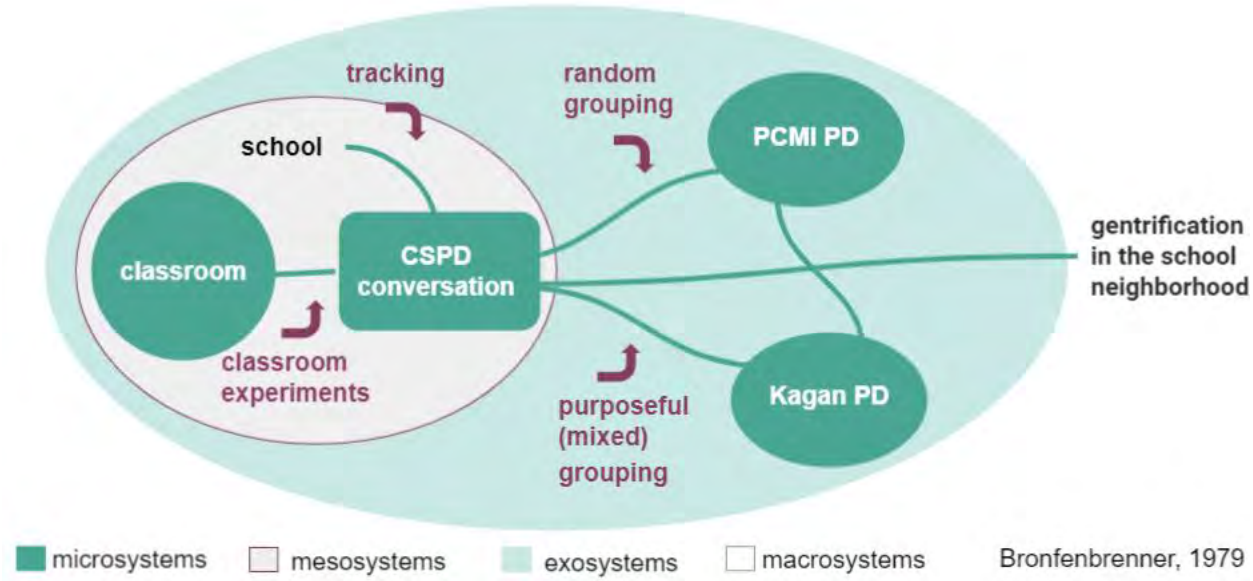

Figure 4: Suggested Scope of an Ecological Perspective on Ezio's CSPD Episode

My point is neither to diminish the value of research on the effects of specific activities (or certain features of activities) on teacher learning, nor to claim that every study of teacher learning must include all possible aspects of teachers' learning ecologies. Rather, I claim that (1) attempts to look at subsystems must be understood as partial (Opfer & Pedder, 2011) and (2) employing more complex perspectives on teacher learning would extend our ability to explain it and consequently to support teachers (Clarke & Hollingsworth, 2002; Horn, 2005).

Importantly, teachers do not experience scales and contexts as separated. In this sense, distinguishing and naming contexts should only be considered as a first step towards studying them as interrelated. In the next section I discuss how ecological models of learning can inform future research towards stronger connections between the immediate and broader contexts of teacher learning ecologies.

Future Research Directions: Connecting Immediate and Broader Contexts of Teacher Learning Ecologies

The claim that we need stronger theoretical connections between the immediate and larger contexts of teacher learning reflects more general calls to see interaction and learning both through a social microscope and a social telescope (Erickson, 2004). I will support this claim by looking at three examples of such calls. The first example comes from the recently published *Handbook of the Cultural Foundations of Learning*, wherein Nasir et al. (2020) conceptualize learning as "occurring along culturally organized learning pathways—sequences of consequential participations and transitions in learning activities that move (or do not move) one towards greater social recognition as competent in particular learning domains and situations" (p. 195). Nasir et al. made the overall claim that focusing only on local learning interactions limits our understanding of the cultural, relational, affective, and contextual nature of learning and their intersections with systems of power.

A second example comes from the work of Fred Erickson. In his book *Talk and Social*

Theory (Erickson, 2004), he likewise pointed out the need to better theorize connections between the immediate contexts of interaction and larger ones. Erickson discussed problems in contemporary social theories with regards to such connections, his main argument being that social theorists such as Foucault, Bourdieu, Gramsci and Fairclough are mostly showing "top-down" influences and are seldom attending to "bottom-up" or "inside-outside" ones. That is, they explain well how social order and structures of power are being reproduced by processes of socialization, normalization, hegemony, and the formation of discourses, but they fail to see the ways persistence and change of structures happens altogether by people in their everyday lives.

Along these lines, a third example is from the work of Gutiérrez and Jurow (2016). Conceptualizing social design experiments, Gutiérrez and Jurow extend traditions of design-based research and call for paying specific attention to ways participants reorganize their systems of activity to disrupt structural and systemic injustices. This emphasis is of particular interest to the world of mathematics education which is rife with normalized injustices and inequities (Chen & Horn, 2020; Louie, 2017). By building on their studies in the contexts of student leadership and food justice movement, Gutiérrez and Jurow (2016) describe different forms of learning, among them developing an understanding of oneself and other with relation to history and systems of power, increasing the capacity to use new conceptual tools, and giving rise to new forms of knowledge that develop across multiple contexts.

Tying the three examples back to the topic of mathematics teacher learning, I discuss how these and other ecological models for learning (Bronfenbrenner, 1979; Cobb et al., 2018; Engeström, 2001; Erickson, 2004; Gutiérrez & Jurow, 2016; Horn et al., 2013; Hutchins, 1995; Nasir et al., 2020) can inform research of teacher learning ecologies. Specifically, I identify three forms of investigations of learning that ecological models highlight (see Figure 5), and then "translate" them into three future directions for research of teacher learning.

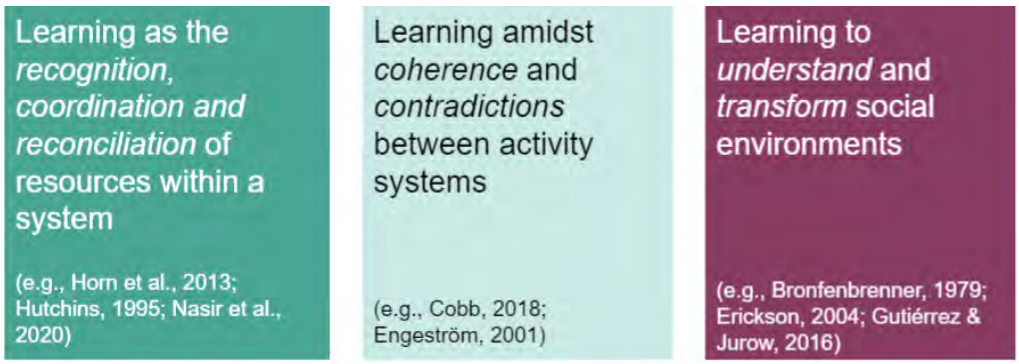

Figure 5: Ecological Forms of Learning Investigations

How do Teachers Reconcile Their Local Contexts With Circulating Resources?

Within the context of activity systems, a main form of learning is the recognition, coordination and reconciliation of resources (Horn et al., 2013; Hutchins, 1995; Nasir et al., 2020). Typically in research on math teachers' learning, resource-centered approaches reflect the linear pathway perspectives (Figure 1), where instructional resources (e.g. practices, curricula, frameworks) are examined in the context of the PD interventions in which they are introduced (Sztajn et al., 2017). An ecological perspective on CSPD suggests the utility of a different resource-centered approach. In CSPD settings, as Ezio's example illustrated, teachers themselves often draw on educational ideas that circulate across settings for their own sensemaking in their

local contexts (Horn, 2005; Stengel, 1991). Indeed, I suggest that a critical aspect in the study of teacher collaborative learning is the articulation of mechanisms by which teachers reconcile local contexts with a range of circulating conceptual resources (Ehrenfeld et al., 2020).

What is the Role of Coherence and Contradictions in Teacher Learning?

In this section, I do not suggest that future research needs to decide whether coherence or contradiction are "better" for learning. Rather, I follow Opfer & Pedder (2011) and suggest that we should focus on causal explanations so that we understand under what conditions, why, and how teachers learn from coherence and contradictions between resources at hand. To do so, I compare and contrast Cobb et al.'s (2018) systematic perspective on teaching improvement efforts with Enge (2001) expansive le arning. On the one hand, Cobb et al.'s (2018) systematic perspective on teaching improvement efforts specifically emphasizes coherence as conducive for instructional improvement towards ambitious and equitable math teaching. Others, such as Engeström (2001), describe contradictions as a force for learning. Engeström (2001) focuses on learning as constructing new practices that emerge from contradictions and hybridization (also Ehrenfeld & Heyd-Metzuyanim, 2019; Ward et al., 2011). We may hypothesize that coherence is more productive for normative and well-defined learning goals; whereas contradictions may be more productive for non-normative and disruptive trajectories.

How do Teachers Learn to Restructure Their Local Environment?

Bronfenbrenner's (1979) goal was to theorize the way people develop within and across changing settings "in both the immediate and more remote environment" (p. 11). He conceptualized human development as follows:

> Human development is the process through which the growing person acquires a more extended differentiated, and valid conception of the ecological environment, and becomes motivated and able to engage in activities that reveal the properties of, sustain, or restructure that environment at levels of similar or greater complexity in form and content. (Bronfenbrenner, 1979, p. 27, emphasis added)

In light of this definition, and in line with the argument that we need to better understand intersections between different contexts of teacher learning, I suggest that we need to investigate both separately and with relation to each other the processes by which teachers learn to reveal, sustain, and restructure their local environments, in particular, with relation to history and the disruption of harmful power relations (Gutiérrez & Jurow, 2016).

Discussion

The overall goal of this conceptual investigation was to work towards understanding teacher CSPD environments in ways that account for the larger contexts of teacher learning ecologies. First, inspired by Bronfenbrenner's work, I suggested an ecological perspective for teacher learning and analytic framework for considering different contexts and scales in the study of teacher conversations. Second, inspired by a larger set of ecological models for learning, I suggested three future research directions for studying these contexts and scales as interrelated. Ultimately, such perspective would open new spaces for thinking about, seeing, and designing for ecological teacher learning in SCPD settings.

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